The Habitable Worlds Observatory Technology Development Plan

2026 July 8

SPIE Astronomical Telescopes & Instrumentation

14145-59

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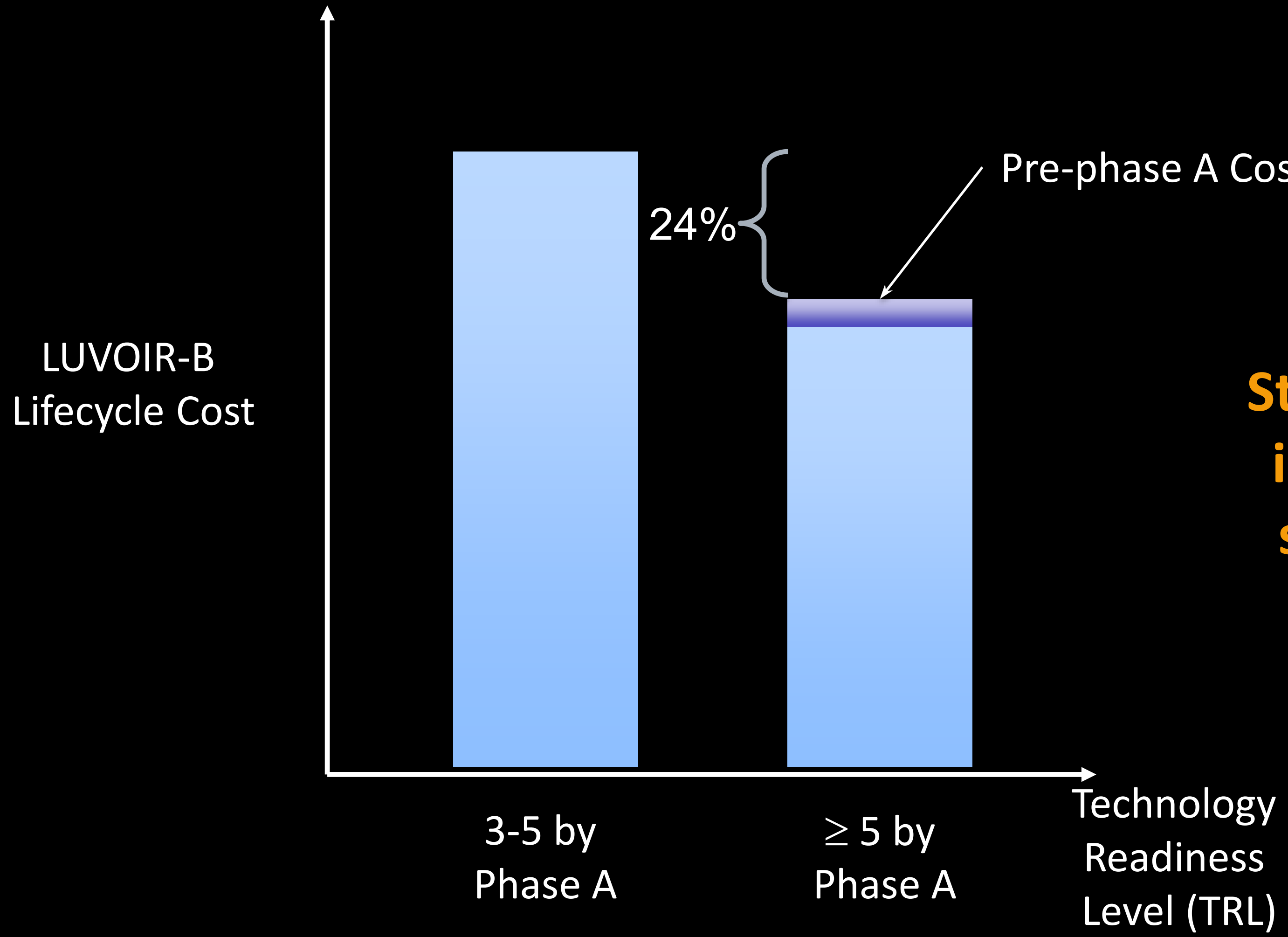
HABITABLE WORLDS OBSERVATORY

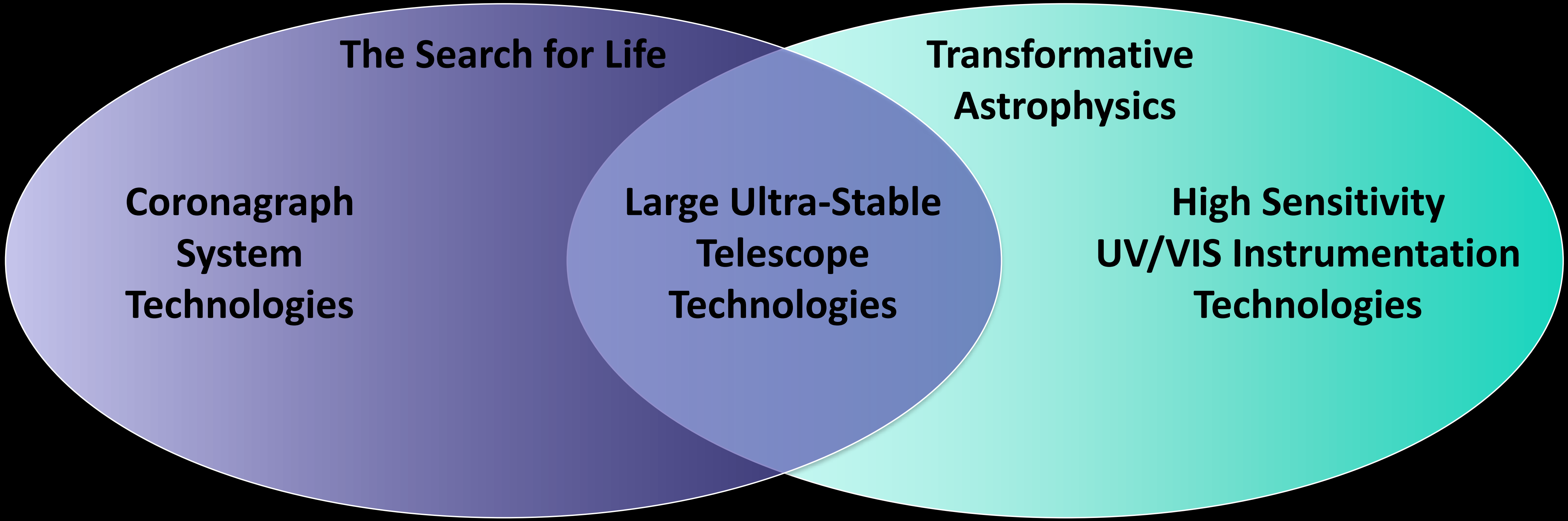
Early Technology Development Saves Money



Strategic investment in Pre-phase A can save cost over the project lifecycle

The LUVOIR Mission Concept Study Final Report, 2019

Technology Needs Are Informed By Science And Architecture



Three Technology Tracks aligned to the system architecture.

HWO's Six Tall Poles

By MCR, we need to show acceptable risk with respect to:

Holding a segmented mirror to the required stability

- Thermal stability of the optical surface
- Active sensing & control of rigid body position
- Backplane dynamic stiffness / stability
- UV-quality surface roughness, wavefront, edge roll-off

HWO's Six Tall Poles

By MCR, we need to show acceptable risk with respect to:

Holding a segmented mirror to the required stability

Achieving end-to-end system-level alignment & stability

- Active sensing & control of system-level alignments
- Large-scale dynamic isolation & stability
- Large-scale thermal stability

HWO's Six Tall Poles

By MCR, we need to show acceptable risk with respect to:

Holding a segmented mirror to the required stability

Achieving end-to-end system-level alignment & stability

Reaching & maintaining the necessary contrast & contrast stability
- Design & fabricate masks & components with necessary accuracy
- Control wavefront & amplitude errors with DMs
- Actively sense necessary modes during science operations
- Post-process images to required contrast floor

HWO's Six Tall Poles

By MCR, we need to show acceptable risk with respect to:

Holding a segmented mirror to the required stability

Achieving end-to-end system-level alignment & stability

Reaching & maintaining the necessary contrast & contrast stability

Detection & characterization of exoEarths with photon-counting detector systems

- Required QE and total noise rate with appropriate ConOps
- Feasible operating temperatures
- Radiation hard & robust to environments

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Reaching & maintaining the necessary contrast & contrast stability

Detection & characterization of exoEarths with photon-counting detector systems

A feasible deployment scheme
- Accommodate aperture, micrometeoroid, stray light, and thermal constraints
- Meets mass and volume constraints of available fairings

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Detection & characterization of exoEarths with photon-counting detector systems

A feasible deployment scheme

Far-UV coatings

- Uniform, repeatable, high-reflectance
- Environmentally robust
- Characterization of polarization and scatter impacts on coronagraphy

HWO's Six Tall Poles

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Detection & characterization of exoEarths with photon-counting detector systems

A feasible deployment scheme

Far-UV coatings

HWO TMPO is investing strategically to advance each technology.

Partnering with Industry (1/3)

Seven contracts awarded, comprising 13 Technology Demonstrations & 10 Mission Architecture Studies

1. Astroscale U.S.
2. BAE Systems
   - The University of Arizona
   - JPL
3. Busek Space Propulsion and Systems
   - University of California Irvine
   - JPL
4. L3Harris
   - Anoplate
   - Precise Cables Inc
   - Corning
   - Frontgrade
   - Specialty Materials
   - JPL
   - Toray Innovation by Chemistry
   - McQuillen Manufacturing
   - Vacuum Innovations
   - Optimax
5. Lockheed Martin
   - The University of Arizona
   - Magma Space
   - Chicks in Space
   - Soloh Space Collective
   - UF University of Florida
   - Tony Hull
6. Northrop Grumman
   - BAE Systems
   - L3Harris
   - Kratos
   - The Scatter Works, Inc
   - Applied Aerospace
   - NeXolve
7. Zecoat

Partnering with Industry (2/3) – System Demonstrations

BAE SYSTEMS

Developing sub-scale segment phasing demo incorporating edge sensors, ultra-fine actuators, and laser metrology

L3HARRIS™

Demonstrate sub-milli-Kelvin thermal control and picometer wavefront stability; also developing 2-m coating capabilities

LOCKHEED MARTIN

Develop active, non-contact disturbance isolation system and perform end-to-end system performance modeling

NORTHROP GRUMMAN

Investigate ultra-stable structures, latches, and materials; investigate micrometeoroid protection approaches

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All four teams also performing mission architecture studies and parametric modeling in support of HWO systems design team.

Partnering with Industry (3/3) – Targeted Efforts

Investigate innovative, cost-effective solutions to serviceability and servicing architectures

Investigate microthruster lifetime and develop capability for HWO applications

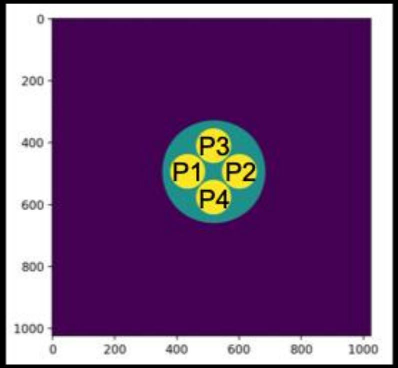
Demonstrate Al+LiF mirror coating uniformity and repeatability on 1.8-meter class optics

DEMONSTRATING ULTRA-STABILITY WITH NASA EXPERTISE (1/3)

Mini-MUST (Metrology and Ultra-Stable Testbed) Chamber capable of validating picometer-level performance of meter-class test articles

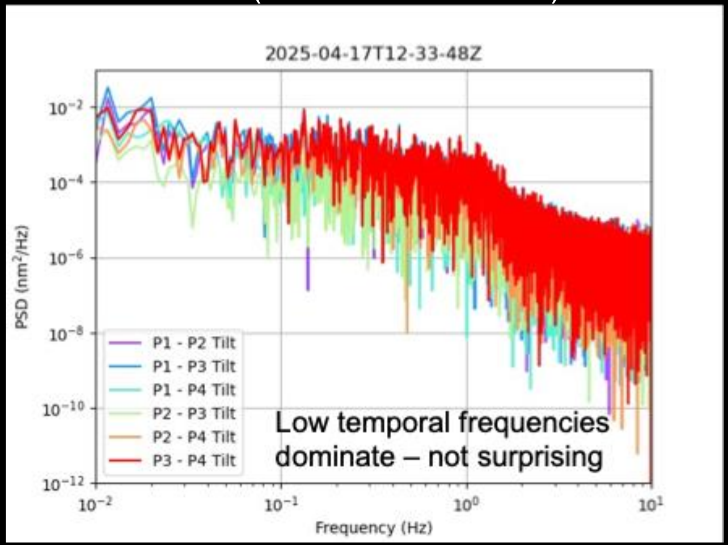
- Thermal stability <±1 mK over hours
- Vacuum levels ≤ 10^{-5} Torr
- Test articles ≤ 1-m in diameter
- Partnering with D.19 teams and academia to test mirrors, structures, and metrology critical for HWO

T. Hadjimichael and G. Hilton outside the mini-MUST chamber with test article (Credit: NASA/GSFC)



Ultra-stable performance leverages expertise gained in the pico-chamber, achieving picometer-level stability with 5” optics

	Weighted σ (pm)		
0.01 - 10 Hz	Piston	Tip	Tilt
P1 - P2	2.07	3.99	8.81
P1 - P3	2.62	1.60	3.92
P1 - P4	2.85	6.76	5.09
P2 - P3	4.61	4.16	4.40
P2 - P4	6.38	4.23	8.08
P3 - P4	4.63	4.96	5.41



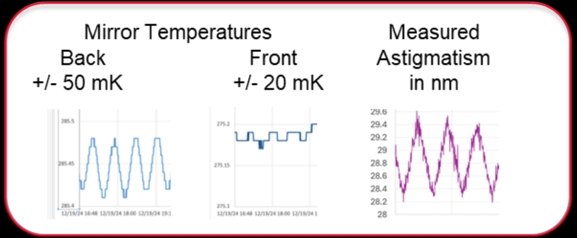
 Credit: NASA GSFC

Demonstrating Ultra-stability with NASA Expertise (2/3)

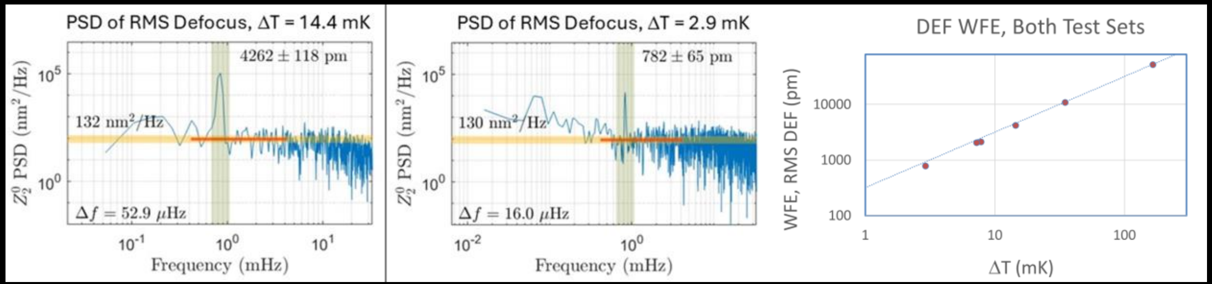
Marshall Space Flight Center developing thermal control algorithms and micrometeoroid damage models:

Thermal Modulation Testing (TMT)

Measure mirror's optical response to thermal stimuli of different amplitude & period
→ Apply frequency-domain analysis



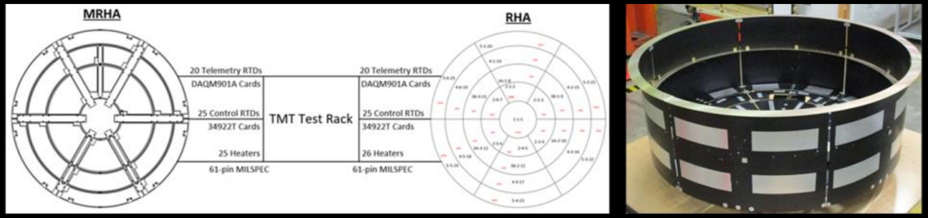
Credit: NASA MSFC

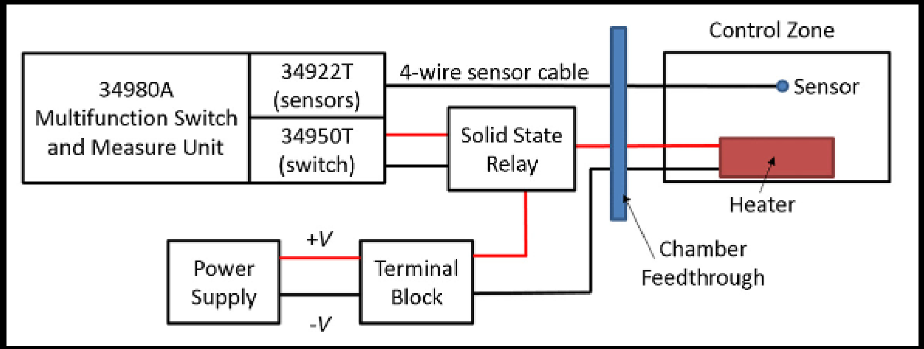


TMT of closed-back BK-7 mirror shows linear thermal response at the pm/K level

Precision Thermal Control (PTC)

Demonstrates 25 independent thermal control zones with < 2 mK RMS stability





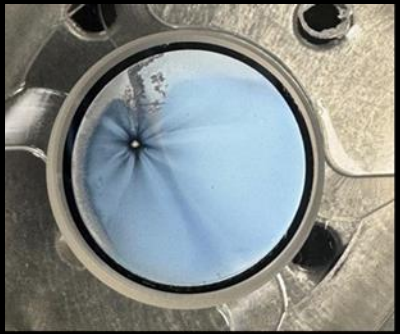
Credit: NASA MSFC

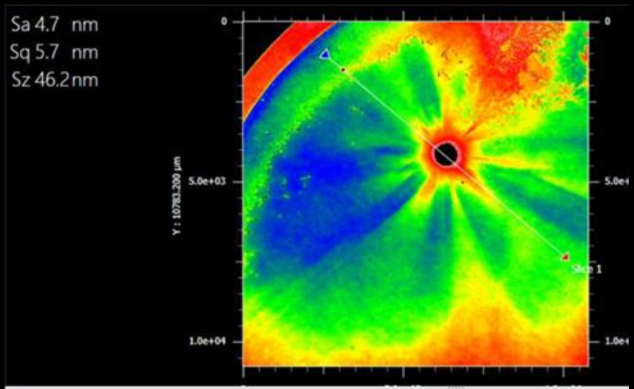
Demonstrating Ultra-stability with NASA Expertise (3/3)

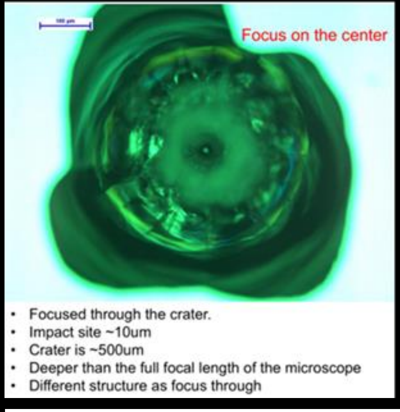
Marshall Space Flight Center developing thermal control algorithms and micrometeoroid damage models:

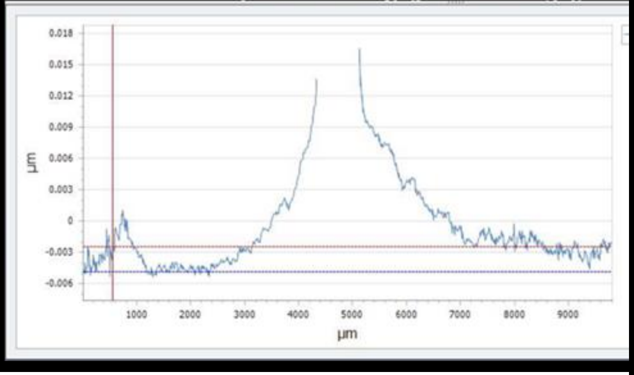
- Micrometeoroids may damage HWO optics and produce scattered light that impacts coronagraphy
- Intent of the study is to:
    - Quantify scattered light from impacts
    - Create predictive model of science longevity
    - Determine best architecture considerations with respect to material & facesheet thickness

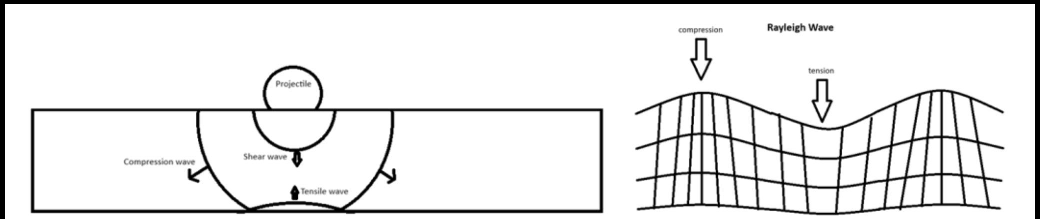
- Test plan duplicates physical environment at Univ. of Colorado IMPACT & White Sands test facilities
    - Energies between 2.5e-11 and 0.0015 J











Credit: NASA MSFC

Building On Roman CGI @ JPL…

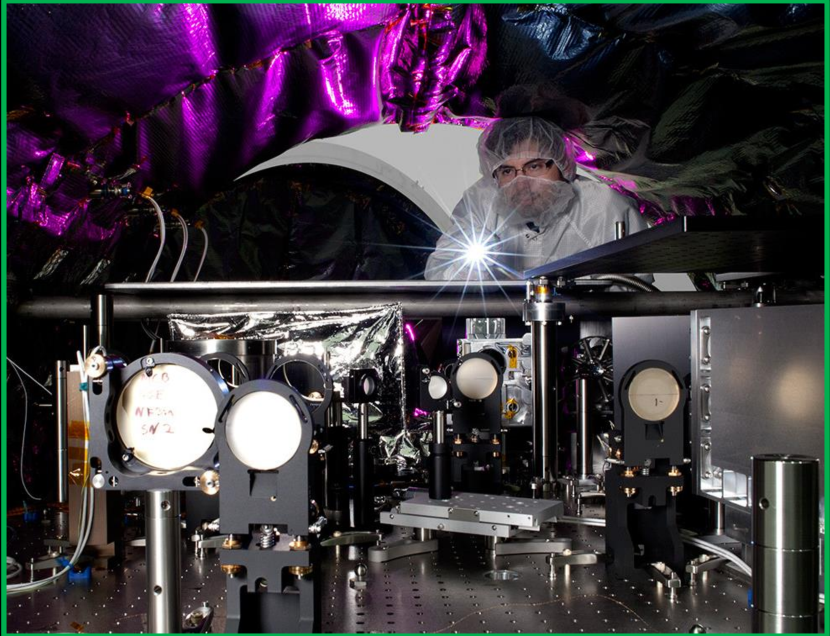
HCIT - High Contrast Imaging Testbeds
DST2 - Decadal Survey Testbed 2
OMC – Occulting Mask Coronagraph
EPIC5 - ExoPlanet Imaging Coronagraph for TRL-5
LOWFS - Low Order WaveFront Sensing

HCIT-DST2: Quasi-static Contrast

Aligned and starting commissioning

Credit: NASA JPL/Caltech

OMC-EPIC5: Contrast Stability



Credit: NASA JPL/Caltech

Design nearly complete; Commissioning early next year

- Dual-testbeds for TRL-5 follows CGI success:
  - CGI Key milestone #2: Shaped Pupil Coronagraph @ 1E-8 (narrowband)
  - CGI Key milestone #3: Hybrid Lyot Coronagraph @ 1E-8 (narrowband)
  - CGI Key milestone #4: Coronagraph demo @ 1E-8 and 10% bandwidth
  - CGI Key milestone #5: LOWFS system meets pointing and WFE drift suppression req's

Efforts undertaken on separate testbeds

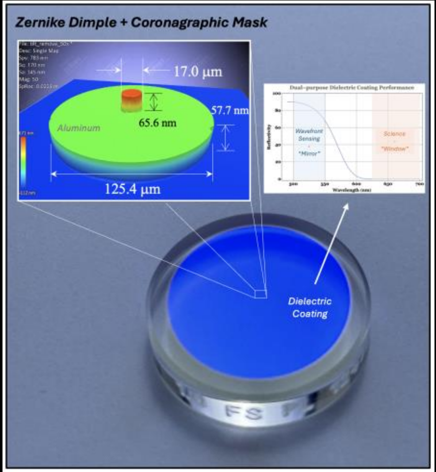
…AND GOING BEYOND (1/3) – MASKS & SPECIALTY OPTICS

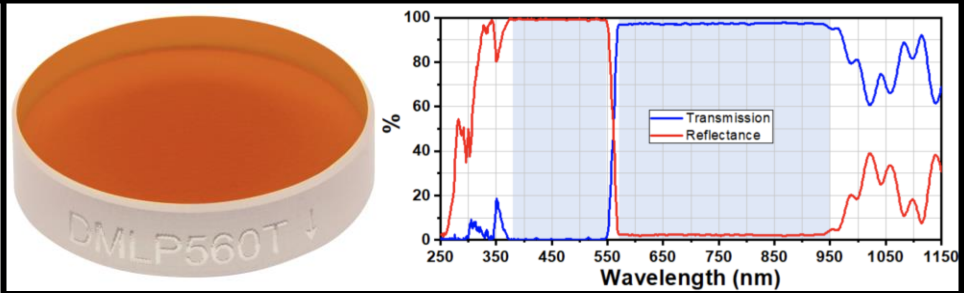
JPL ramping up effort to design, simulate, fabricate, test, and evaluate coronagraph masks for HWO

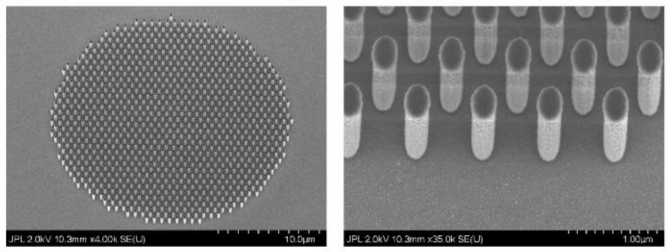
- Trade studies to include scientific yield vs. mask type, fabrication errors, alignment & calibration, etc.
- Fabricate masks and layouts for demonstration on DST2 & EPIC5 testbeds

Also performing analyses in support of specialty optic design & fabrication:

- Broadband dichroics
- Polarization optics
- Dual-purpose focal plane masks







Credit: NASA JPL/Caltech

…AND GOING BEYOND (2/3) - DMS

Phased, parallel investments in deformable mirror (DM) development with Boston Micromachines & AO Xinetics

Phase 1

- Vendors are executing process improvements to address key technology risks
- ~64x64 TRL 5 device each delivered at end of decade

Phase 2

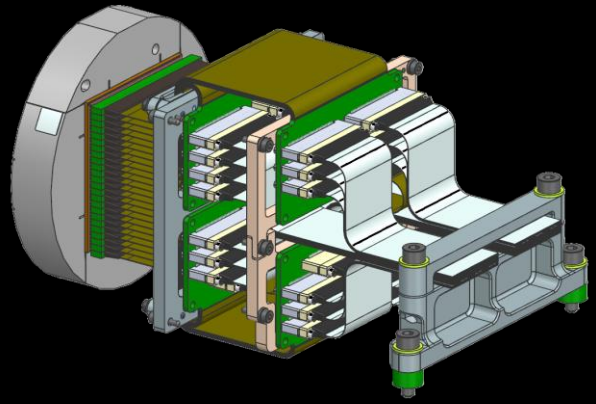
- Chance for second attempt at a full TRL 5 verification
- Two 64x64 TRL 5 devices in 2030

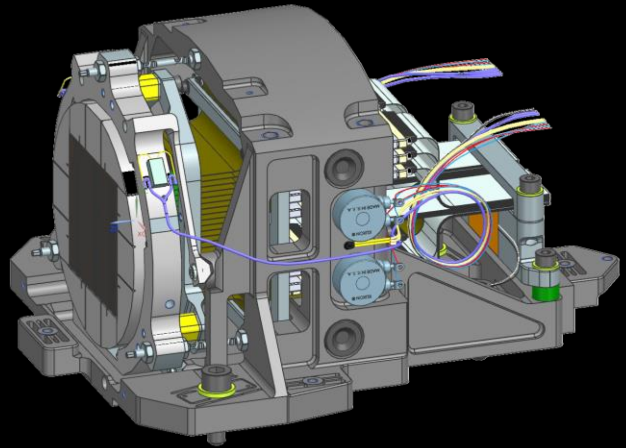
Phase 3

- Two 96x96 TRL 5 devices (delivery TBD, largely based on success of phase 1)

TRL 5 verifications performed on vacuum surface gauge at JPL with complementary verifications done on testbeds in development at Goddard

JPL also developing interconnect concepts to mitigate challenges encountered on Roman CGI



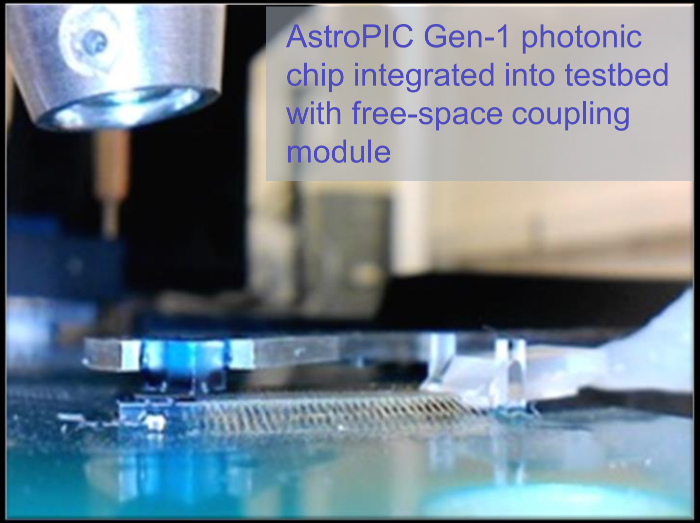


Credit: NASA JPL/Caltech

…AND GOING BEYOND (3/3) - PHOTONICS

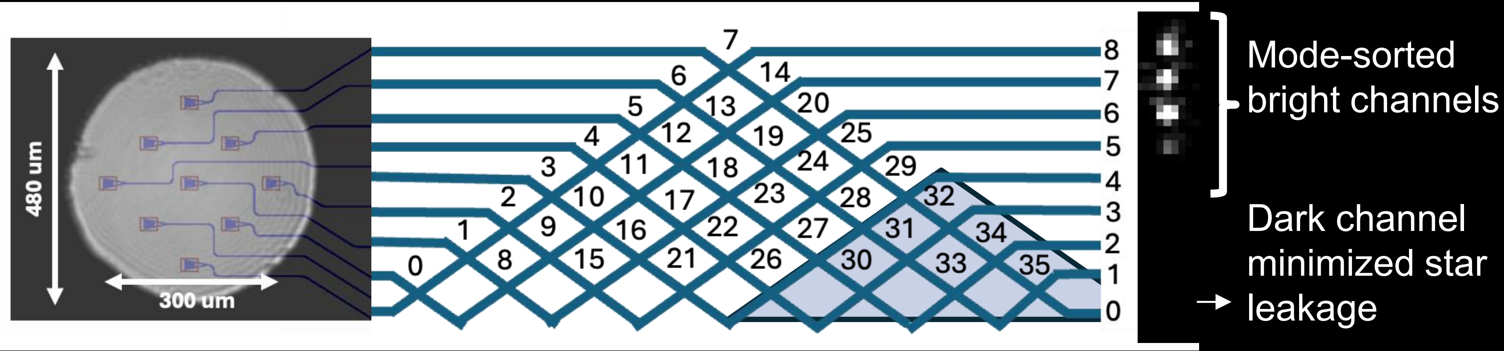
Investigating NIR photonic-based coronagraph solutions at Ames Research Center (in-air testbed)

- ***2.0e-9 suppression*** on-chip (first light demonstration, Sept 2025)
- ***3.5e-10 suppression*** on-chip (component demonstration, Jan 2026)
- ***8.7e-8 contrast*** free-space coupling (TRL-3 system demo , Mar 2026)
- ***AstroPIC Gen-2 chip submitted to foundry*** (May 2026, spatial input channels 9 → 16, high-efficiency grating coupling, mono → 1% band)



Credit: NASA ARC

Also developing NIR vacuum coronagraph testbed, Multi-star wavefront control techniques, and phase-induced amplitude apodization (PIAA)-vortex coronagraph



Credit: NASA ARC

See talks: 14145-280, -279, -282, -98

DETECTOR SYSTEM DEVELOPMENT STUDY

Partnering with Columbus Technologies on 2-phase effort to mature detector systems

Addresses needs for visible & NIR coronagraph detectors, Far-UV detectors, and Near-UV/visible large-format detectors

Phase 1: Define complete technology development plan for candidate technologies to TRL 5

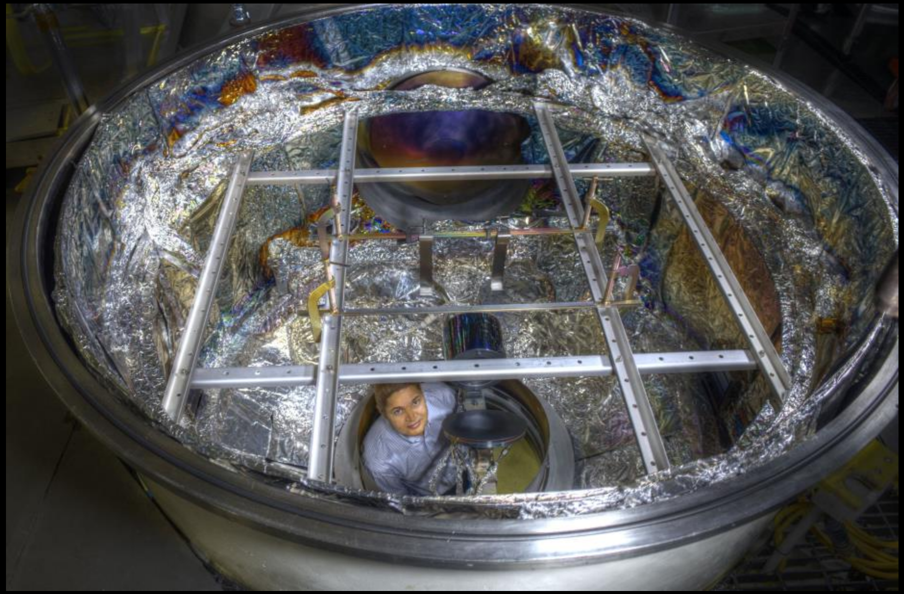
Phase 2: Execute technology development plan

Call closed July 7, 2026

PAVING THE WAY FOR FAR-UV SENSITIVITY

GSFC completing development of 2-m coating chamber measure repeatability, uniformity, polarization, and scatter properties of Al+XeLiF coating on 1.5-m-class optics

- Working closely with partners at Zecoat and L3Harris to transfer the capability to industry



Credit: NASA GSFC

Both GSFC & JPL developing Atomic Layer Deposition (ALD) techniques for enhanced Far-UV filters and gratings

CONCLUSION

The HWO Technology Maturation Project Office has invested in a comprehensive portfolio of development efforts with our industry, academic, and NASA Center partners

Our technology development plan continues to evolve with ongoing science, architecture, and design concept investigations